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Economic analysis of PV systems on buildings in Sicilian farms

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ABSTRACT

The photovoltaic sector in Italy in recent years has experienced a rapid growth also in the primary sector, thanks to substantial incentives guaranteed by energy policies, simultaneous reduction of investment costs and tax benefits.

In order to better understand the growth of the PV industry in Italian primary sector, the aim of this paper has been to evaluate the economic convenience of four PV systems on farm buildings located in four different farms of the north-western coast of Sicily and realized during the second and fourth Italian feed-in schemes. For each feed-in scheme it has been considered a PV plant that sells the electricity to the grid and another in which the energy generated is consumed entirely by the farm.

The results show a clear convenience to the realization of investments both with the current market conditions and at the variation of the feed-in tariff or the investment costs.

Contents

1. Introduction

Renewable energy sources such as hydropower, biomass, geothermal, wind and solar represent a viable alternative to traditional fossil fuels both for the benefits in terms of reduced impact on the environment and for their ability to be renewable and not subject to depletion [1,2].

These energy sources contribute to the achievement of targets set by the Kyoto Protocol, limiting the consumption of fossil fuels, reducing the release of greenhouse gases into the atmosphere and avoiding sanctions for signatory States in case of defaults [3].

Over the last years renewable energy sources have had a growing impact in European Union electricity production after the approval of Directive 2001/77/EC that provided a framework for the development of renewable energy technologies in Europe [4].

European policy in support of renewable sources has continued with the Directive 2009/28/EC (better known as the "20–20–20" targets) that set as objective for EU the achievement of a share of 20% from renewable sources in 2020 in the consumed energy mix [5].

According to the latest available data, in fact, the energy produced from renewable sources in 2011 accounted for 20.4% of total gross electricity production, with an increase of 48.7% compared to 2005 (Table 1).

The diffusion of renewable energies is due to the their reduction of costs that, despite are higher than fossil fuels, are also falling more rapidly, helping to close the gap between these sources of power. This reduction comes from the efforts of policy-makers to support the development of renewable electricity

Abbreviations: PV, photovoltaic; CE, Conto Energia; CBA, cost–benefit analysis; NPV, net present value; DPBT, discounted payback time; IRR, internal rate of return; FiT, feed-in tariff

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Table 1
Electricity production in EU (GW h) [6].

Items	2005	2006	2007	2008	2009	2010	2011
Total gross production (*A*)	3,310,643	3,354,764	3,367,476	3,371,287	3,209,053	3,346,283	3,279,778
Renewable sources (*B*)	450,910	477,718	509,836	551,543	585,652	667,249	670,387
$(B/A)\times 100$	13.6	14.2	15.1	16.4	18.3	19.9	20.4

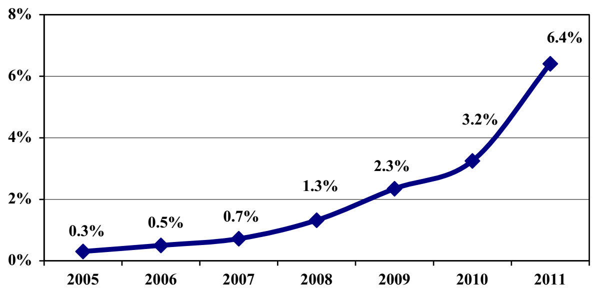

Fig. 1. Share of PV electricity production in renewable sources in EU [13].

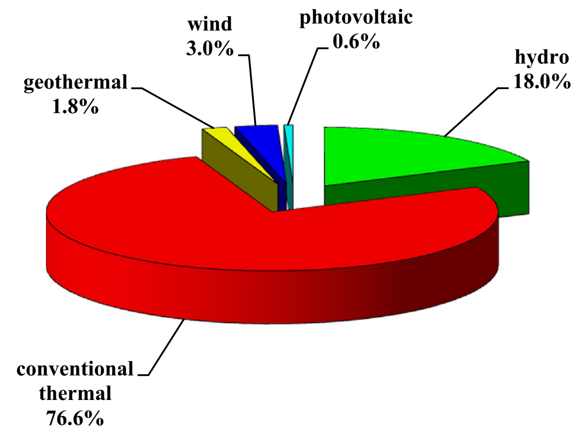

Fig. 2. Electricity gross production in Italy (2010) [15].

Table 2
PV sector in European Union (2011) [14].

Country	Cumulated capacity (MW)	Installed capacity (MW)	Electricity production (GW h)
Germany	24,875.0	7505.0	19,340.0
Italy	12,786.5	9303.0	10,795.7
Spain	4345.3	402.0	7386.0
France	2924.8	1732.0	2015.0
Czech Republic	1959.1	0.0	2118.0
Belgium	1391.1	487.0	1169.6
UK	978.3	899.3	252.0
Greece	631.3	425.9	610.0
Slovakia	488.2	314.1	20.0
Bulgaria	203.0	170.7	120.0
Austria	187.2	91.7	174.1
Portugal	158.5	32.5	277.0
Netherlands	145.0	57.0	100.0
Others	200.3	80.9	156.0
Total UE	**51,273.6**	**21,501.1**	**44,533.4**

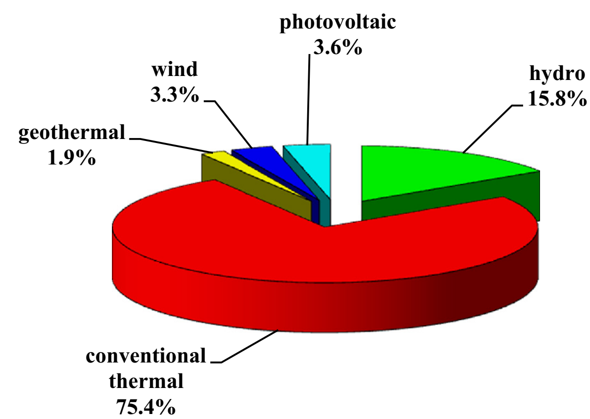

Fig. 3. Electricity gross production in Italy (2011) [15].

technology, either through direct means such as government-sponsored research and development (R&D) or by enacting policies that support the production of renewable electricity, such as renewable energy certificates and feed-in tariffs [7].

The expansion of the energy sector related to renewable sources is due mainly to the development of PV industry which has benefited from substantial incentive mechanisms present in various countries [8–10]. This has attracted the interests of many small investors and, especially, of large financial groups which have decided to invest in solar energy [11], playing a key role in European energy policies [12].

PV sector development has led the PV industry to produce, within a few years, 6.4% of electricity deriving from renewable sources (Fig. 1).

The main European country for the electricity production from PV panels is Germany, which in 2011 amounted a cumulated capacity equal to 24,875.0 MW, accounting for 48.5% of total capacity in European Union (Table 2).

Italy, with a cumulated capacity equal to 12,786.5 MW, is the second producer of electricity from PV panels (24.9% of the European Union), followed by Spain (4345.3 MW), France (2924.8 MW), Czech Republic (1959.1 MW) and Belgium (1391.1 MW). These six countries account for 94.2% of the EU cumulated capacity.

With regard to electricity produced from PV systems, these six countries provide 96.2% of the EU total. In particular, Germany represents the first country with 19,340.0 GW h, followed by Italy (10,795.0 GW h), Spain (7386.0 GW h), Czech Republic (2118.0 GW h), France (2015.0 GW h) and Belgium (1169.6 GW h).

Considering PV installed capacity in 2011, however, it can be observed that Italy represents the main country with 9303.0 MW, followed by Germany (7505.0 MW) and France (1732.0 MW).

Taking into account last two years, Italy has increased the share of electricity generated from solar panels, from a value of 0.6% to a 3.6% (Figs. 2 and 3).

The sudden diffusion of the PV industry in Italy over the last times is imputable to the Italian feed-in scheme, better known as Conto Energia (CE) that, through feed-in tariff (FiT), has rapidly expanding the share of PV sector in overall electricity mix, as well as in other countries [16–19].

Moreover, the growth of PV sector has generated a positive effect in terms of employment, creating from 2002 to 2010 more

than 100,000 jobs, of which about 20,000 direct employees with an average age under 35 years [20].

In 2011, however, the main energy source is represented by conventional thermal which represented 75.4% of the total electricity gross, followed by hydropower (15.8%).

These data show that in Italy, despite renewable energy sector provides 24.6% of the electricity production, there is still a strong dependence on traditional fossil fuels.

For the development of the Italian PV sector, over the last years, a key role has been played by agriculture. The primary sector, in fact, increased its relevance in terms of installed capacity, passing from 9% (2009) to 15% (2012) of total Italian installed capacity deriving from PV plants, representing the second sector after the Industry (60%) [21].

The growth of PV plants in Italian primary sector is attributable to the inclusion, by public legislator, of energy production from renewable sources among activities related to agriculture that, as such, can enjoy a range of tax benefits [22]. All this involves lower business risks as a function of incentives granted by public operator [23]. This decision derives from the fact that the electricity production from renewable sources, as well as the PV sector, makes the farm more competitive and sustainable, diversifying income opportunities of farmer and directs it toward an increasingly multifunctional role, according to the main guidelines of EU agricultural policy [24].

The evolution occurred in primary sector in the last years, involved mainly the PV systems on farm buildings. At the end of 2012, in fact, in Italy 48% of the PV systems is placed on buildings, 43% on ground, 6% on greenhouses or roofs/covers and the remaining part is on other sites.

This growth is attributable to the Italian feed-in scheme that, starting from its second version, granted higher values of FiT to the PV systems on buildings than PV plants on ground. The reason of this differentiation is that among the various types of possible PV systems the placement of PV modules on farm buildings avoids the heavy debate on the destination of land use because, unlike the ground systems, it does not subtract areas for the cultivation of agricultural products. The PV systems on ground, in fact, are not only in competition with agricultural activities for the land occupation, but subtract it for very long periods (at least 20 years) and, what is worse, compromise its fertility, making particularly difficult a future recovery for agricultural purposes [25]. Moreover, incidence of PV systems on buildings increased starting from 2012, when legislator has forbidden the installation of PV systems on agricultural soil [26].

PV panels installed on buildings represent a solution to the problem and the large availability of areas guaranteed by farm buildings can be exploited by farmers respecting the environmental and landscape equilibrium of territory for the benefit of a new environmentally sustainable image of their agricultural activity [27].

From a strictly economic viewpoint, the purchase of a PV system means an expenditure of capital resources at a given time with the expectation of benefits in the form of solar electricity yield to be paid/saved to/by the user over the useful life of the system. Any economic assessment on such an investment requires a calculation of the involved cash flows as consistent as possible [28].

Therefore in order to better understand the growth of the PV industry in Italian primary sector, the aim of this paper has been to evaluate the economic convenience of four PV systems on farm buildings located in four different farms of Sicilian north-western coast and realized during the second and fourth CE. For each feed-in scheme it has been considered a PV plant that sells the electricity to the grid and another in which the energy generated is consumed entirely by the farm (net metering).

In this way it has been possible to evaluate the economic convenience of PV systems on farm buildings according to energy destination (sold or saved) and two different Italian feed-in schemes.

The financial indicators used in the economic analysis have been the net present value (NPV), the discounted payback time (DPBT) and the internal rate of return (IRR).

All PV systems have been realized through a bank loan but, in order to give an economic evaluation that does not depend by the different conditions of bank loan access, the financial indicators have been calculated by considering several values of bank debt: 0% (investments realized entirely with own capital), 25%, 50%, 75% and 100% (investments realized entirely with bank loan).

Finally, in order to extend economic assessments to a range of variability related to different scenario hypothesis it has been carried out a sensitivity analysis, by varying the investment costs and the FiT.

2. Evolution of Italian feed-in scheme

Over the years, with the succession of feed-in schemes, there has been a sudden expansion of the PV industry that has led to a reduction of price for the PV systems, decreased of 50% in Europe during the last five years [29], and to an increase of the objectives set by the legislator.

For these reasons the Italian legislator has tried to find a solution to balance the level of public support with the costs of technologies, giving stability and certainty to the market. To this end tariffs have been reduced in a few years with a succession of different regulatory interventions, reflecting an inadequate forecast of PV industry development and potential.

The Italian feed-in scheme, called also Conto Energia (CE) and aimed at the incentive of electricity production by PV systems, nowadays has reached its 5th edited version.

Since 2005, in fact, five different feed-in schemes have became operational, pushing the Italian legislator to raise the threshold of installed capacity derived from solar panels to be achieved by 2020 from 8 to 23 GW [30].

Unlike previous remuneration policies, with the approval in 2005 of first CE revenue grants have been designed for PV systems with a nominal capacity greater than 1 kW, over a period of 20 years [31,32]. In this initial stage, value of PV incentive depended mainly on the size of PV systems (Table 3).

Tariff is aimed at ensure a reasonable payback time and it is paid through a withdrawal in energetic bills of all the consumers.

In 2007 second CE introduced some changes, as well as the simplification of bureaucratic practices to obtain PV incentives, a tariff differentiation based on typology and size of PV plants [33].

In particular, specific tariffs assigned to PV plants on buildings have been introduced with the second CE that distinguished partially and totally integrated PV systems according to the position of the module relative to the roof of the building.

Moreover, second CE introduced tariff increases for particular PV plants (replacement of eternit or asbestos, PV systems realized in public school or health facility, etc.).

Table 3
Tariffs (€/kW h) for PV systems according to 1st Conto Energia[a].

Installed capacity (kW)	PV plants
$1 \le P \le 20$	0.445
$20 < P \le 50$	0.460
$50 < P \le 1000$	0.490

[a] Values referred to 2005.

With regard to the second CE, the highest values of FiT are related to PV systems with a nominal capacity from 1 to 3 kW (Table 4). The second CE established that the values of FiT decreased for every year after 2008 of 2%.

In PV systems with equal installed capacity, highest incentives were granted for building-integrated PV systems and lower tariffs for PV plants installed on ground.

In 2010, with the approval of third CE [34], it has been defined a further distinction of PV plants, distinguishing four main system categories: (a) PV systems on buildings; (b) other PV systems; (c) integrated PV plants with innovative features; and (d) concentrating PV plants.

Compared to second CE, the third CE set a differentiation of FiT in six classes related to the installed capacity and, for PV systems on buildings, it has resolved the distinction between partially and totally integrated plants (Table 5). However, highest tariffs have been allocated to building-integrated PV (BIPV) with innovative features, which had to guarantee the installation of modules with substantial architectural functions (thermal control of the building, waterproofing, resistance).

In 2011 fourth CE [35] did not set substantial changes, but just a reduction to tariffs allocated to PV systems commissioned between 1 June 2011 and 31 December 2016 and a simplification of PV systems in two main typologies.

With regards to fourth CE, the legislator has set values of feed-in tariffs lower than those set for third CE, in order to contain public spending, according to the growth of PV sector attributable to substantial incentives and reduction of price for the PV systems (Table 6). The fourth CE established that the values of FiT decreased for every month in 2011 and for every six months starting from 2012.

Furthermore, fourth CE introduced the distinction between “small and great PV plants”, whereas the latter was obligated to a registration in a specific register for the access at the PV incentives.

All the four regulatory interventions include feed-in tariff as type of remuneration policy to encourage PV installations. This kind of tariff provides a fixed-price contract per kW h of generated energy for a 20 years period, to which it has to be added the revenues from the electricity fed into the grid, subjected to price fluctuations. In alternative the electricity fed into the grid can be economically offset with the value of electricity withdrawn from the grid service (net metering) [36].

First CE set a threshold of 20 kW for PV systems which demanded net metering whereas starting from third CE net-metering raised the power of not over 200 kW. Therefore, while in the other countries the FiT is paid only for the energy effectively sold to the Utility, in Italy the producer receives a FiT for the whole produced electric energy and a payment for the part of electric energy sold to the Utility [37].

The major benefit of FiT is that private independent producers receive a long-term minimum guaranteed price for the electricity they generate.

The feed-in tariff is used in many EU countries because it seems to be the most effective method to increase the diffusion of the energy generation systems, as it ensures a long-term investment with a low risk for investors, regardless any future price fluctuations in the energy market [38–40].

The fifth CE [41] has been the last feed-in scheme adopted by Italian government. It entered into force on August 2012, after that the annual indicative cumulative cost of incentives has reached 6 billion Euro. Incentive tariffs of this feed-in scheme are granted to PV plants (divided by type of installation), building integrated PV plants with innovative features and concentrating PV plants.

Unlike the previous support schemes, the fifth CE grants an all-inclusive FiT to the share of net electricity injected into the grid and a premium tariff to the share of net electricity consumed on site, abolishing net metering (Table 7). Thus, if a plant generates electricity for self-consumption, the applicable tariff is given by the sum of the all-inclusive tariff for the share of net generation injected into the grid and of the premium tariff for the share of net generation consumed on site.

Moreover, fifth CE introduced the obligation of the subscription to the register also for small PV plants.

Starting from 6 July 2013, fifth CE has ceased to have effect, because it has been reached the indicative cumulative cost of incentives of €6.7 billion per year.

Currently, Italian government allows to realize PV residential systems deducting taxes from 50% of the installation costs until 31

Table 4
Tariffs (€/kW h) for PV systems according to 2nd Conto Energia[a].

Installed capacity (kW)	PV plants on ground	PV plants on buildings (partially integrated)	PV plants on buidings (integrated)
$1 \leq P \leq 3$	0.400	0.440	0.490
$3 < P \leq 20$	0.380	0.420	0.460
$P > 20$	0.360	0.400	0.440

[a] Values referred to 2008.

Table 5
Tariffs (€/kW h) for PV systems according to 3rd Conto Energia[a].

Installed capacity (kW)	PV plants on buidings	Other PV plants
$1 \leq P \leq 3$	0.402	0.362
$3 < P \leq 20$	0.377	0.339
$20 < P \leq 200$	0.358	0.321
$200 < P \leq 1000$	0.355	0.314
$1000 < P \leq 5000$	0.351	0.313
$P > 5000$	0.333	0.297

[a] Values referred to 2011.

Table 6
Tariffs (€/kW h) for PV systems according to 4th Conto Energia[a].

Installed capacity (kW)	PV plants on buidings	Other PV plants
$1 \leq P \leq 3$	0.387–0.274	0.344–0.240
$3 < P \leq 20$	0.356–0.247	0.319–0.219
$20 < P \leq 200$	0.338–0.233	0.306–0.206
$200 < P \leq 1000$	0.325–0.224	0.291–0.172
$1000 < P \leq 5000$	0.314–0.182	0.277–0.156
$P > 5000$	0.299–0.171	0.264–0.148

[a] Values between June 2011 and June 2012.

Table 7
Tariffs (€/kW h) for PV systems according to 5th Conto Energia[a].

Installed capacity (kW)	PV plants on buidings		Other PV plants	
	All inclusive FiT	Premium tariff	All inclusive FiT	Premium tariff
$1 \leq P \leq 3$	0.208–0.182	0.126–0.100	0.201–0.176	0.119–0.094
$3 < P \leq 20$	0.196–0.171	0.114–0.089	0.189–0.165	0.107–0.083
$20 < P \leq 200$	0.175–0.157	0.093–0.075	0.168–0.151	0.086–0.069
$200 < P \leq 1000$	0.142–0.130	0.060–0.048	0.135–0.124	0.053–0.042
$1000 < P \leq 5000$	0.126–0.118	0.044–0.036	0.120–0.113	0.038–0.031
$P > 5000$	0.119–0.112	0.037–0.030	0.113–0.106	0.031–0.024

[a] Values between August 2012 and August 2013.

December 2013, looking forward to a new regulatory regarding other PV typologies [42].

According to latest available data, despite the continuous reduction applied to PV incentives, there has been a continuous development of the PV industry, realizing 536,919 PV systems, which correspond to an installed capacity of 17,144,415 kW (Fig. 4).

The growth of PV sector in Italy is mainly attributable to the capacity installed during second and fourth CE. The first CE, in fact, has been characterized by a capacity of 163,431 kW, while with the second CE it has been installed a total capacity equal to 6,790,293 kW. The third CE has been characterized by an installed capacity of 1,565,486 kW, while the fourth CE has reached 7,639,269 kW. The fifth CE, finally, denotes an installed capacity of just 985,936 kW.

3. Methodology and case study

The cost–benefit analysis (CBA) is a financial valuation technique used to predict the effects of a project, a program or an investment, verifying if from its realization the investor can obtain or not a benefit [44,45]. CBA, as an alternative to traditional methods of economic analysis, represents also a method of ex-ante evaluation by external parties that have to decide on financial viability of investment or have to choose how to allocate scarce financial resources among different possible investments [46].

In order to evaluate the economic convenience of PV systems on buildings it has been carried out the CBA of the four detected case studies.

The objective of the economic analysis is to determine the costs and the benefits of investment and to quantify with the determination of appropriate financial indicators the economic convenience of four PV systems [47]. The discounted cash flows generated from each investment have been calculated for 20 years, equal to the period in which incentives are granted by Italian feed-in scheme.

In particular the financial indicators used for economic analysis have been: the net present value (NPV), the discounted payback time (DPBT) and the internal rate of return (IRR).

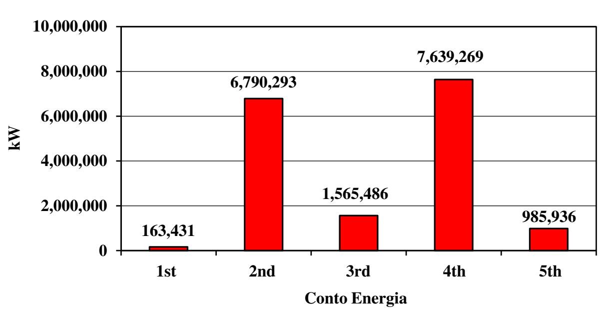

Fig. 4. Installed capacity according to Conto Energia [43].

The NPV represents the discounted annual cash flows, according to the following formula:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \tag{1}$$

where C_t represents the discounted annual cash flows; t is the time of the cash flow; n corresponds to the lifetime of investment and r is the discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk).

According to this financial indicator greater is its value, higher will be the convenience of the investment.

The discounted annual cash flows are obtained from the difference between the annual revenues (inflows) and costs (outflows):

$$C_t = I_t - O_t \tag{2}$$

where I_t represents the discounted annual cash inflows and O_t is the discounted annual cash outflows.The discounted annual cash inflows are calculated by:

$$I_t = E_{PV}(\mathrm{FiT} + P_u \varepsilon_{Pu}) \tag{3}$$

where E_{PV} represents the annual generated energy from PV system; FiT corresponds to public incentive granted per kW h of generated energy; P_u is the unitary price per kW h to be paid or saved by the owner; ε_{Pu} is the annual increase rate of the PV electricity unitary price saved by the owner, while in PV systems in which energy is sold to the grid, it has been utilized an average value of electricity price.The discounted annual cash outflows include:

$$O_t = C_{PV} + (C_m + C_i)\varepsilon_c + Q_b \tag{4}$$

where C_{PV} represents the initial cost of PV system (if the investment is realized with own capital); C_m and C_i are, respectively, the cost of maintenance and insurance of PV panels; ε_c is the annual increase rate of the maintenance and insurance PV costs, taken into consideration in order to bring the costs up to date; Q_b represents the quota related to the bank loan (if the investment is realized with bank loan). It is clear that in the determination of the financial index acquires fundamental importance the choice of the discount rate. The discount rate should assume values applicable to the type of investment under consideration as a function of the economic and financial environment which is referred the evaluation. In order to perform correctly the economic judgment of the investment convenience, it has been chosen a value of the discount rate equal to Weighted Average Cost of Capital (WAAC). The WACC is the rate that a company is expected to pay on average to all its security holders to finance its assets. The WACC is the minimum return that a company must earn on an existing asset base to satisfy its creditors, owners, and other providers of capital, or they will invest elsewhere. In our case the WAAC is equal to 5%.

However, this financial indicator proves to be unsuitable for choosing between two projects with the same NPV but different initial cost requirements and lifetimes [48].

Table 8
Main tecnichal–economic characteristics of case studies.

Case	Financing	Annual interest rate for the loan (%)	PV capacity (kW)	PV electricity yield (kW h kW^{-1} year^{-1})	Investment cost (€/kW)	Revenues	
						FiT (€/kW h)	Electricity sold/saved (€/kW h)[a]
A	Bank loan	4	20	1500	4500	0.460	0.140
B	Bank loan	4					0.100
C	Bank loan	5			2500	0.268	0.140
D	Bank loan	5					0.100

[a] Values referred to 2012.

The DPBT represents the number of required years so that the cumulative discounted cash flows equate the initial investment. This financial indicator is not an out-and-out measure of the economic convenience of investment, but rather of rapidity in which liquidity reforms itself, because it does not consider the discounted cash flows generated after the DPBT and it may hide sound financial opportunities for those deciding to invest in a PV system [49].

Considering that NPV calculation depends on the reference discount rate used, for which the same investment may be convenient or less in relation to its value, it is useful to consider as financial indicator also the IRR, because its value does not depend on the reference discount rate chosen but only on the entity and temporal evolution of the benefits and costs.

The IRR is the discount rate at which the discounted benefits are equal to the discounted costs, determining a net present value equal to zero.

Mathematically, the internal rate of return represents the discount rate for which the following equation is satisfied:

$$\sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = 0 \tag{5}$$

For a given project, the IRR equals the actual interest rate at which the project initial investment should be lent during its useful life to achieve the same profitability [50].

According to this indicator, an investment is convenient if its IRR is higher than a predetermined reference discount rate to which the investor otherwise could invest his financial liquidities.

This financial indicator, however, can be calculated in the event that a sequence of negative discounted cash flows (that normally are present in the first years of the investment) is followed by positive discounted cash flows [51].

The economic analysis has been carried out in 2012 on four PV systems on farm buildings located in four different farms of the north-western coast of Sicily and realized during the second and fourth CE, the two Italian feed-in schemes within which there have been the highest values for installed capacity.

For each feed-in scheme it has been considered a PV plant that sells the electricity to the grid and another in which the energy generated is consumed entirely by the farm. Each one has an installed capacity of 20 kW (Table 8).

In particular, four PV systems have been taken into consideration:

(A) PV plant in which the energy generated is consumed entirely by the farm installed during the second CE;
(B) PV plant that sells the electricity to the grid installed during the second CE;
(C) PV plant in which the energy generated is consumed entirely by the farm installed during the fourth CE;
(D) PV plant that sells the electricity to the grid installed during the fourth CE.

The cases (A) and (B) have been realized in 2008, while (C) and (D) in 2011.

For the realization of PV systems have been used multicrystalline silicon panels, a less expensive material than the monocrystalline one, because of the simpler manufacturing process required, even if slightly less efficient [52,53].

For the purpose of energy production, it has been considered an annual average electricity production of 1500 kW h/kW [54]; the annual PV electricity yield generated by the system is assumed to decrease every year by 0.8% [55,56].

The lifetime of PV plants has been considered equal to 20 years, coincident with the period during which feed-in tariffs are granted.

All PV systems have been realized through a bank loan for a depreciation period of 10 years but, in order to give an economic evaluation that does not depend by the different conditions of bank loan access, the financial indicators have also been calculated by considering several values of bank debt: 0% (investments realized entirely with own capital), 25%, 50%, 75% and 100% (investments realized entirely with bank loan).

The annual interest rates adopted to pay off the bank loan amounted to 4% for PV plants installed during the second CE and 5% for those installed in the fourth CE. The difference observed in the interest rates is due to the different conditions of access to bank loan, which have worsened in the last feed-in scheme for an unfavorable economic situation.

Table 9
Economic analysis results.

Case	100% Bank loan			75% Bank loan			50% Bank loan			25% Bank loan			Own capital		
	NPV (€)	IRR (%)	DPBT (years)	NPV (€)	IRR (%)	DPBT (years)	NPV (€)	IRR (%)	DPBT (years)	NPV (€)	IRR (%)	DPBT (years)	NPV (€)	IRR (%)	DPBT (years)
A	108,747	–	0.0	106,664	39.47	3.0	104,581	25.97	4.5	102,499	20.84	5.5	100,416	17.96	6.5
B	87,516	–	0.0	85,433	33.54	3.5	83,350	22.66	5.5	81,267	18.37	6.5	79,185	15.92	7.5
C	89,616	–	0.0	89,031	57.58	2.0	88,446	35.54	3.0	87,860	27.79	4.0	87,275	23.63	5.0
D	64,767	–	0.0	64,181	44.63	2.5	63,596	28.67	4.0	63,011	22.85	5.0	62,425	19.64	6.0

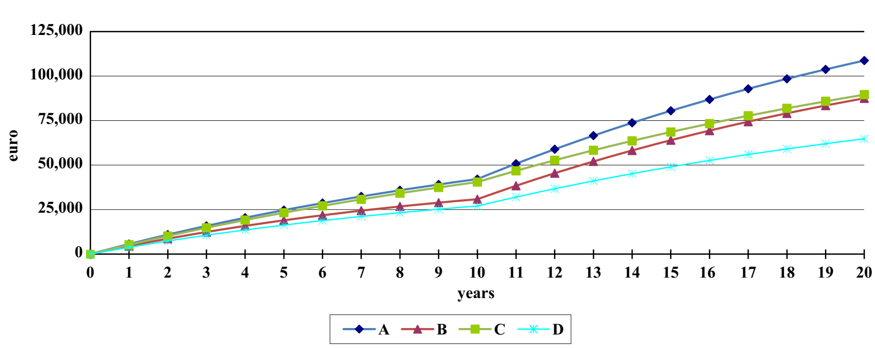

Fig. 5. Discounted cash flows of case studies with 100% bank loan.

With regard to the investment costs of PV systems, over the years there has been a decrease of 44%, passing from a value of 4500€/kW to one of 2500€/kW. This decrease is attributable to the expansion of the PV sector that has led to a reduction of PV panels [57].

Considering these investment costs, cases (A) and (B) has required a total expenditure of 90,000€, while the plants (C) and (D) of 50,000€.

The annual cost of maintenance of the PV panels has been estimated equal to 0.018€/kW h, while the annual cost of insurance amounted to 0.4% of investment costs [58].

As regards the revenues of four facilities, for each PV plants it has to take into consideration a quota deriving from the FiT plus one deriving from the sold or saved energy. The cases (A) and (B) have granted a feed-in tariff equal to 0.460€/kW h, against a value of 0.268€/kW h for (C) and (D) cases.

Regarding PV systems that sell the energy produced to the grid ((B) and (D) cases), it has been considered an average price of electricity of 0.10€/kW h. For PV plants in which the energy generated is consumed entirely by the farm ((A) and (C) cases) it has been taken into account the relative savings in the electricity bill imputing a price of 0.14€/kW h, at which it has been applied an annual revaluation rate equal to 2.2% [59]. This revaluation has been also applied to the costs of maintenance and insurance of PV panels.

4. Results and discussion

Financial indicators (NPV, DPBT and IRR) for each case study, taking into consideration PV systems realized with several values of bank loan and own capital, are shown in Table 9.

Cases (A) and (C) (net metering) registered values of financial indicators most convenience within each feed-in scheme analyzed, because the savings resulting from the energy consumed have been higher than the revenues of the corresponding energy sold to the grid.

Financial indicators denoted not only a higher convenience of investments that consume the electricity produced (cases (A) and (C)) but, except NPV, have also highlighted best values for PV plants installed during the fourth CE (cases (C) and (D)).

The major economic convenience of cases (C) and (D) compared to (A) and (B) ones is due to the reduction of investment costs (−44.4%) occurred between two different Italian feed-in schemes, which has been able to compensate for the relative reduction of the unitary value of the FiT (passed from 0.460 to 0.268€/kW h).

The PV plants realized with 100% bank loan showed highest values of NPV, ranging from a minimum of 64,767€ to a maximum of 108,747€.

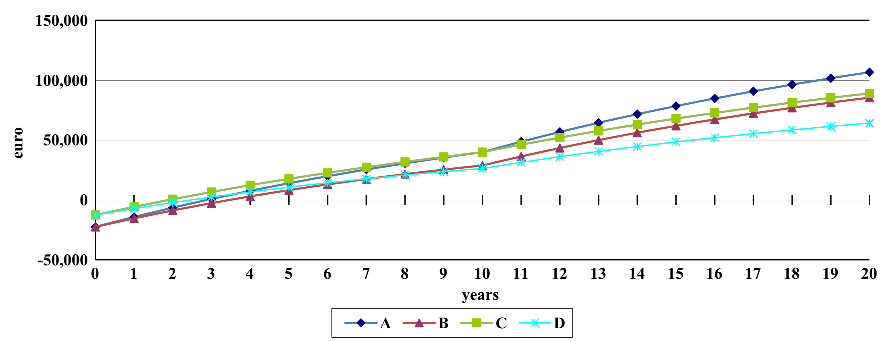

Fig. 6. Discounted cash flows of case studies with 75% bank loan.

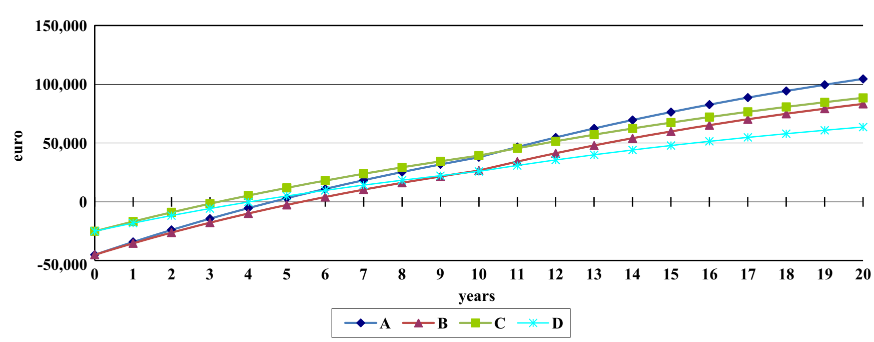

Fig. 7. Discounted cash flows of case studies with 50% bank loan.

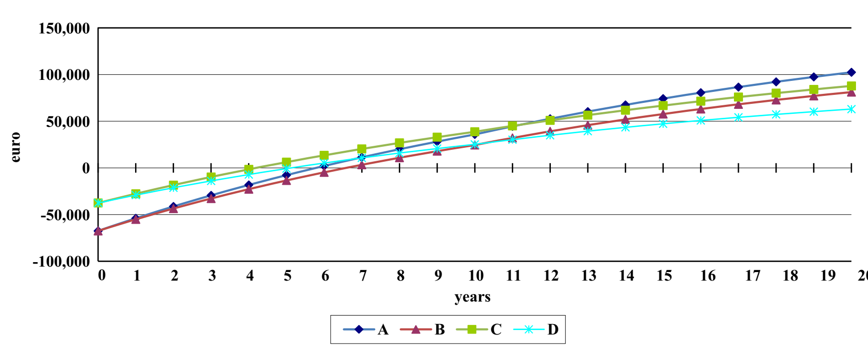

Fig. 8. Discounted cash flows of case studies with 25% bank loan.

For these PV systems has not been possible to calculate the IRR as it is in the presence of positive discounted cash flows from the first year of the investment, determining a DPBT equal to zero (Fig. 5).

The high revenues of PV systems, in fact, far outweigh the costs, among which the quota to extinguish the bank loan is the most representative item.

For other PV plants realized with several levels of bank debt, results have showed a decreasing economic convenience of financial indicators, passing from 75% to 25% of bank loan.

The NPV registered a value between 106,664€ (case (A)) and 63,011€ (case (C)). The IRR and DPBT, as above mentioned, denoted higher economic convenience in PV plants realized during the fourth CE. In particular, case (C) showed a IRR between 57.58% (75% bank loan) and 27.79% (25% bank loan), while DPBT ranged from 2.0 to 4.0 years (Figs. 6–8).

The PV systems realized with own capital showed financial indicators worse than their respective cases realized with different levels of bank loan. The initial cost of the investment entirely supported by the investor, has determined a value of NPV between 100,416€ and 62,425€ and also in this case higher values are attributable to PV systems with the net metering. PV plants realized with own capital denoted a DPBT value, that graphically coincides with the point where the straight line representing discounted cash flows intersects the axis of abscissas, ranged from 5.0 to 7.5 years (Fig. 9).

As regards IRR of PV systems, it has been observed a value between a minimum of 15.92% and a maximum of 23.63%.

5. Sensitivity analysis

In order to provide a more exhaustive economic assessment of PV systems, such as made by different authors [60–62], it has been carried out a sensitivity analysis, by varying separately the two main parameters that affect on a convenience judgment of a PV system: the investment cost and the FiT.

For each parameter two different scenarios have been proposed, imputing values lower (Scenario A) and higher (Scenario B) than 50% compared to the reference cases, determining for each PV plant new financial indices. The sensitivity analysis has been carried out also taken into consideration the annual increase rate both for the PV electricity unitary price sold or saved by the owner and for maintenance and insurance PV costs.

The simulations are shown in Tables 10 and 11.

The sensitivity analysis confirmed for all PV systems and economic convenience also increasing the investment costs or reducing the FiT but, as well as for economic results, showed a decreasing economic convenience of financial indicators, passing from 100% bank loan to 0% bank loan (own capital).

As regards the NPV, the two hypothesized scenarios encountered the same percentage changes. The PV systems realized during the second CE (cases (A) and (B)) have been the most sensitive both to a change of the FiT and of the investment costs. Within the same feed-in scheme the cases that sell the energy to the grid ((B) and (D)) showed the greatest percentage variation. Comparing the two parameters taken into consideration, it is observed as a FiT variation had a most influence on the NPV value

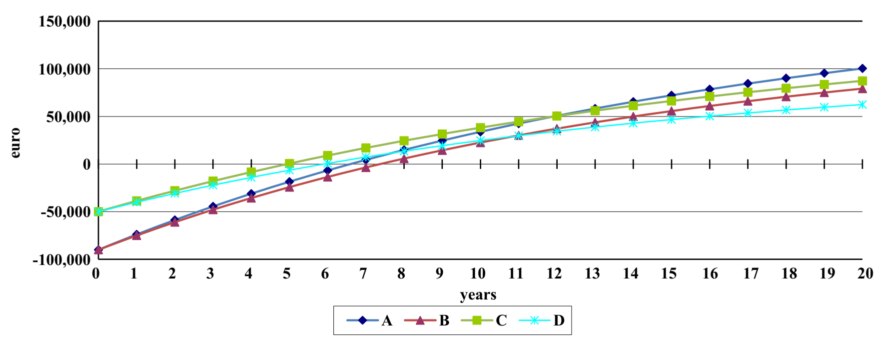

Fig. 9. Discounted cash flows of case studies with own capital.

Table 10
Sensitivity analysis of case studies. Scenario A (−50%).

Case	Parameter	100% bank loan			75% bank loan			50% bank loan			25% bank loan			own capital		
		NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)
A	Investment cost	155,717	–	0.0	154,676	118.57	1.0	153,635	65.34	1.5	152,593	47.59	2.5	151,552	38.61	2.0
	FiT	34,220	26.77	11.5	32,137	14.55	12.0	30,054	11.78	12.0	27,972	10.31	12.5	25,889	9.36	13.0
B	Investment cost	134,486	–	0.0	133,445	107.18	1.0	132,404	59.38	1.5	131,362	43.45	2.5	130,321	35.37	3.0
	FiT	12,899	12.09	15.0	10,906	9.06	16.0	8823	7.84	16.5	6740	7.13	17.0	4658	6.66	18.0
C	Investment cost	116,854	–	0.0	116,562	157.45	1.0	116,269	85.20	1.5	115,976	61.12	1.5	115,684	49.03	2.5
	FiT	46,196	–	0.0	46,611	28.50	5.0	45,025	20.67	6.5	44,440	17.31	7.5	43,885	15.31	8.0
D	Investment cost	166,225	–	0.0	91,712	132.67	1.0	91,420	72.40	1.5	91,127	52.34	2.0	90,834	42.25	2.5
	FiT	21,347	56.23	9.5	20,761	16.68	11.0	20,176	13.30	11.0	19,591	11.62	11.0	19,005	10.56	11.0

(from 47.7% to 94.1%) respect to investment costs changes (from 30.9% to 64.6%).

The DPBT, as well as the NPV, showed the greatest differences for cases (A) and (B), and for the PV systems that sell the electricity ((B) and (D)). In particular, the decrease of the investment costs (Scenario A) determined values between 0.0 and 3.0 years, while in the opposite scenario ranged from 0.0 to 14.0 years. The reduction of the FiT, vice versa, highlighted a DPBT between 0.0 and 18.0 years, while its increase showed values between 0.0 and 4.5 years.

Considering the IRR, in all cases a reduction of 50% of the investment costs (Scenario A) determined an increase of the value of IRR between 19.45 and 99.87 points, while in the opposite scenario the increase of the investment costs highlighted a reduction of the IRR between 7.36 and 30.85 points. Regarding the FiT, a reduction (Scenario A) showed a decrease of the IRR value variable between 8.32 and 29.08 points, while the opposite scenario denoted its increment ranged from 7.95 to 31.76 points.

The results of sensitivity analysis showed two significative differences between NPV and IRR.

The first difference is that the IRR compared to the NPV highlighted that the detected case studies resulted more sensitive to the variation of the investment costs (especially to their reduction) than the FiT, causing a greater variability within the same scenario.

The second is that according to the IRR the PV systems installed during the fourth CE (cases (C) and (D)) have been the most sensitive to the variations of investment costs in both scenarios.

The results therefore denoted the importance that assumed the reduction of investment costs in the realization of a PV system. This could be one of the explanations to the rapid diffusion of the PV industry in Italian primary sector, confirmed by the decreasing of the investment costs measured in recent years.

6. Conclusions

In recent years Italy has highlighted a rapid growth of the PV sector, in correspondence with the entry into force of the feed-in scheme, better known as the Conto Energia.

This diffusion has also affected the primary sector, where many farmers have decided to install PV systems, diversifying their income and making farm increasingly sustainable and multifunctional, as well as promoted at EU level.

The growth of PV plants in Italian primary sector is attributable to the inclusion, by public legislator, of energy production from renewable sources among activities related to agriculture that, as such, can enjoy a range of tax benefit. This evolution affected mainly PV systems on farm buildings because Italian feed-in scheme, starting from its second version, granted higher value of FiT to the PV systems on buildings than PV plants on ground.

In this context, in order to better understand the rapid expansion of the PV sector in Italian primary sector, the aim of this paper has been to evaluate the economic convenience of four PV systems on buildings installed in different farms of Sicilian north-western coast.

The detected PV systems have been realized during the second and the fourth CE, the two Italian feed-in schemes within which there have been the highest values for installed capacity.

The results showed a clear economic convenience of PV systems.

In PV systems realized with 100% bank loan, the discounted cash flows resulted always positive, determining in all cases a DPBT equal to zero and the NPV value ranged from 64,767 to 108,747€.

For other PV plants realized with several levels of bank debt, results have showed a decreasing economic convenience of financial indicators, passing from 75% to 0% of bank loan.

Considering the cases in which PV systems have been realized entirely with own capital, the investment costs totally supported by the entrepreneur involved values of DPBT between 5.0 and 7.5 years, a NPV lower (from 62,425 to 100,416€) and a IRR ranged from 15.92% to 23.63%.

The financial indicators showed a higher convenience of investments in which the electricity produced is consumed entirely by the farm (net metering) and, except NPV, in those realized during the fourth CE. This is attributable to savings resulting from the energy consumed that have been higher than the revenues of the corresponding energy sold to the grid and to reduction of investment costs that occurred between two different Italian feed-in schemes.

The sensitivity analysis confirmed for all PV systems an economic convenience also increasing the investment costs or reducing the FiT.

In particular, the parameter that denoted the most influence on the economic convenience of PV systems has been the investment costs, highlighting the importance that its reduction occurred over the years has had in the growth of the PV industry involving also the Italian primary sector.

Table 11
Sensitivity analysis of case studies. Scenario B (+50%).

Case	Parameter	100% bank loan			75% bank loan			50% bank loan			25% bank loan			own capital		
		NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)	NPV (Euro)	IRR (%)	DPBT (years)
A	Investment cost	61,776	63.53	1.5	58,652	16.85	11.0	55,528	13.24	11.0	52,404	11.42	11.5	49,280	10.27	12.0
	FiT	183,274	–	0.0	181,191	69.07	1.5	179,108	40.69	2.5	177,026	31.00	3.5	174,943	25.91	4.5
B	Investment cost	40,545	23.13	12.0	37,421	13.14	12.5	34,297	10.70	12.0	31,173	9.40	13.5	28,049	8.56	14.0
	FiT	162,043	–	0.0	159,960	63.16	1.5	157,877	37.55	3.0	155,794	28.76	4.0	153,712	24.12	4.5
C	Investment cost	62,378	–	0.0	61,500	26.73	5.0	60,622	19.56	7.0	59,744	16.43	7.5	58,866	14.57	8.5
	FiT	133,036	–	0.0	132,451	89.17	1.5	131,866	51.08	2.5	131,280	38.28	3.0	130,695	31.70	3.5
D	Investment cost	37,529	–	0.0	36,651	18.74	10.0	35,773	14.60	10.0	34,894	12.61	10.5	34,016	11.38	10.5
	FiT	108,187	–	0.0	107,602	76.39	1.5	107,016	44.42	2.5	106,431	33.63	3.5	105,845	28.03	4.0

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